NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

MENTAL MODELS FOR TIME DISPLAYED TASKS

by

Joyce D. Fleischman

June 1988

Thesis Advisor Judith H. Lind

Unclassified

security classification of this page

REPORT DOCUMENTATION PAGE

1a Report Security Classification Unclassified	1b Restrictive Markings
2a Security Classification Authority	3 Distribution Availability of Report Approved for public release; distribution is unlimited.
2b Declassification Downgrading Schedule	
4 Performing Organization Report Number(s)	5 Monitoring Organization Report Number(s)
6a Name of Performing Organization Naval Postgraduate School — 6b Office Symbol *(if applicable)* 32	7a Name of Monitoring Organization Naval Postgraduate School
6c Address *(city, state, and ZIP code)* Monterey, CA 93943-5000	7b Address *(city, state, and ZIP code)* Monterey, CA 93943-5000
8a Name of Funding Sponsoring Organization — 8b Office Symbol *(if applicable)*	9 Procurement Instrument Identification Number
8c Address *(city, state, and ZIP code)*	10 Source of Funding Numbers Program Element No — Project No — Task No — Work Unit Accession No

11 Title *(include security classification)* MENTAL MODELS FOR TIME DISPLAYED TASKS

12 Personal Author(s) Joyce D. Fleischman

13a Type of Report	13b Time Covered	14 Date of Report *(year, month, day)*	15 Page Count
Master's Thesis	From To	June 1988	64

16 Supplementary Notation The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

17 Cosati Codes			18 Subject Terms *(continue on reverse if necessary and identify by block number)*
Field	Group	Subgroup	mental models,IAAS,human factors,time-displayed task

19 Abstract *(continue on reverse if necessary and identify by block number)*

The study described in this thesis attempts to determine whether there is a mental model for time-ordered tasks. The results of this study may be used to assist in the design of cockpit display formats for the Intelligent Air Attack System (IAAS) in the F/A-18, A-6 or other Navy and Air Force tactical aircraft, and may be applicable to telecommunications systems as well. Basic human factors engineering concepts and the characteristics of IAAS and of the Naval Telecommunications System are described. The approach and methodology for determining whether there is a consistent mental model for time-ordered tasks is discussed, and the results of a survey are presented. Based on this survey, it was determined that mental models for time-ordered tasks are not always the same, but instead are task-dependent. Schedules are most logically presented in a calendar-like format. For telecommunications related tasks, a front-to-back format is recommended. For time-ordered events in an aircraft cockpit, a top-to-bottom display order was preferred by a majority of study participants, but aviators preferred a left-to-right presentation.

20 Distribution Availability of Abstract ☒ unclassified unlimited ☐ same as report ☐ DTIC users	21 Abstract Security Classification Unclassified
22a Name of Responsible Individual Judith H. Lind	22b Telephone *(include Area code)* (408) 646-2543 — 22c Office Symbol 55Li

DD FORM 1473,84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete

security classification of this page

Unclassified

Approved for public release; distribution is unlimited.

Mental Models for Time Displayed Tasks

by

Joyce D. Fleischman
Lieutenant, United States Navy
B.A., State University of New York, College at Buffalo, 1976

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN TELECOMMUNICATIONS SYSTEMS
MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
June 1988

Author: ______________________________
Joyce D. Fleischman

Approved by: ______________________________
Judith H. Lind, Thesis Advisor

____
Benjamin J. Roberts, Second Reader

____
for David ~~R. Whipple~~, Chairman,
Department of Administrative Science

____
James M. Fremgen,
Acting Dean of Information and Policy Sciences

ABSTRACT

The study described in this thesis attempts to determine whether there is a mental model for time-ordered tasks. The results of this study may be used to assist in the design of cockpit display formats for the Intelligent Air Attack System (IAAS) in the F A-18, A-6 or other Navy and Air Force tactical aircraft, and may be applicable to telecommunications systems as well. Basic human factors engineering concepts and the characteristics of IAAS and of the Naval Telecommunications System are described. The approach and methodology for determining whether there is a consistent mental model for time-ordered tasks is discussed, and the results of a survey are presented. Based on this survey, it was determined that mental models for time-ordered tasks are not always the same, but instead are task-dependent. Schedules are most logically presented in a calendar-like format. For telecommunications related tasks, a front-to-back format is recommended. For time-ordered events in an aircraft cockpit, a top-to-bottom display order was preferred by a majority of study participants, but aviators preferred a left-to-right presentation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

A. THE INTELLIGENT AIR ATTACK SYSTEM AND MENTAL MODELS

The Intelligent Air Attack System (IAAS) is a prototype integrated avionics software system that is presently under development at the Naval Weapons Center (NWC), China Lake, California. The system under development is designed for the missions of the F/A-18, A-6, or other Navy and Air Force tactical aircraft in the early 1990s. This system has been the cooperative effort of human factors, radar, and electronic warfare specialists. It is in the advanced development stage. [Ref. 1 : pp. 1-2]

The IAAS is a knowledge based system which will assist the combat pilot by enhancing his capabilities to make decisions. The formats for the displays will be designed for rapid mental processing. This is an automated system, where the pilot will be able to select the level of automation desired. Various task agendas will be displayed to cue the pilot for a specific action or to show that an automated action has been completed. The best way to display these time-dependent tasks has not been determined, since little is known about how people think of time, that is, about their mental models of time when it is depicted in two-dimensional space.

By interacting with the environment, other people, and technology people form internal mental models of themselves and about those things with which they are interacting. Models aim to provide predictive and explanatory power for understanding this interaction. Mental models fulfill an extensive role in human reasoning [Ref. 2: p. 10].

Mental models can be determined by careful examination of the way people understand some domain of knowledge. This study is an attempt to discover whether there is a mental model for time. Use of display formats which are intuitive for most people will reduce mental processing time for decision making, planning, and action selection. Since excessive mental workload is a major problem facing pilots today a reduction in mental processing time would be of great benefit.

Thus, the purpose of this study is to determine the mental model which best depicts how most people view time-ordered tasks. This model then can be used for design of aircraft displays representing passage of time. The intended readers include the human factors development group at NWC, and also persons with little experience in human

factors who would like to know more about the area and its uses. Research on mental models of time-based tasks also can be applied to another field, telecommunications.

B. MENTAL MODELS FOR THE NAVAL TELECOMMUNICATIONS SYSTEM

The Naval Telecommunications System (NTS) is responsible for providing secure, rapid, and reliable telecommunications services for the operation and administration of the Navy. It is a network made up of many automated subsystems. Automation has also been necessary to handle the growth in message volume experienced in the past few years. Backlogs and overloaded systems are not uncommon.

The results of this research could be applied to user displays for some of the time-dependent telecommunications systems. These options are being examined for possible use within the NTS.

C. GOALS AND OBJECTIVES

The goals of this study are

1. To determine the best kind of display format for time-dependent tasks for the IAAS.
2. To determine applications for this kind of display format in time-dependent telecommunications systems.

The objectives of this study are

1. To introduce the concept of human factors engineering and system design.
2. To develop and administer a survey which will elicit the most commonly thought of mental model for time.
3. To document the results of this survey, for possible use in designing IAAS task agenda displays.
4. To identify possible telecommunications system applications.

II. BACKGROUND

This chapter contains background information concerning human factors engineering. It is intended to help familiarize the reader with some basic concepts and vocabulary used in the human factors area. It is important to establish a basic level of understanding in this relatively new discipline so that the significance of the problems associated with the development of systems for human use can be appreciated, especially as these relate to mental models for use in display format design.

A. DEFINITIONS

Human factors is concerned with designing systems so that people can use them effectively and with producing environments that are well suited for human interaction. The terms "human factors", "human factors engineering", "human engineering", and "ergonomics" are often used interchangeably. The term human factors tends to be the most comprehensive of all these, covering all biomedical and psychosocial considerations applying to man in the system.

Human factors also includes life support, personnel selection and training, training equipment, job performance aids, and performance measurement and evaluation [Ref. 3]. Human factors engineering is concerned with the design and layout of equipment, facilities, and environments. A very simple definition of human factors engineering is designing man-made objects or equipment so that people can use them effectively and safely and creating environments suitable for human living and work [Ref. 4].

B. HISTORY

The idea of human factors actually goes back to pre-historic times where man first developed a weapon or a tool and then looked for a better way to design it. The development of the field had its roots in the industrial revolution of the late 1800s. Frank and Lillian Gilbreth and others published research in the area of motion study and shop management. They believed that work methods provide the basis for differences in skill and effectiveness at various stages of training. These differences in work methods could be analyzed by slow-motion photography to find errors and to teach new workers the superior methods of the skilled worker. [Ref. 5]

The idea of adapting equipment and procedures to people was not explored until World War II, despite the early work contributed by the Gilbreths. Behavioral scientists

during this time period worked mainly on finding the right person for the job and on developing better training programs. However, even with the optimum selection of people to do the job and proper training, the skill to operate the more complex equipment sometimes was still beyond the capabilities of the people chosen. It became obvious that fitting the equipment to the person should be considered. Experimental psychologists were enlisted to collaborate with engineers in designing various military equipment, aircraft cockpits, radar consoles, binoculars, combat information centers, and synthetic training devices. [Ref. 6]

For many working in the area of equipment design research the name "engineering psychology" was adopted. These researchers were mainly interested in determining how best to display information to the senses, how to use human motor output, and how to secure good dynamic characteristics in controller systems. Much of the data resulting from their research on detailed design characteristics has been published in military specifications and design guides which are still in use today.

After World War II, the human factors profession was born. In 1949 the Ergonomics Research Society was established in Britain, and the first book on human factors was published. Over the next ten years conferences were held, laboratories and consulting companies were established, journals were published, and the Human Factors Society was formed. By 1959 an international organization, the International Ergonomics Association, was established to unite human factors and ergonomics societies in many countries around the world. [Ref. 7: p. 7]

In the years 1960 to 1980 the human factors area grew very rapidly. Human factors had been primarily focused in the military-industrial complex. The manned space program quickly made human factors an integral part of its planning and development. Human factors also expanded into many other fields such as computers, pharmaceuticals, automobiles, and other consumer goods [Ref. 7: p. 7]. The importance of designing workspaces to meet human need was made evident by a serious accident at the Three-Mile Island nuclear power facility, where the complexity of the control room was a case of poor human engineering and resulted in catastrophic operator errors.

Today, human factors continues to grow as a science. The boom in the computer industry has made human factors considerations a requirement in the design of equipment and the development of "user friendly" software. Systems like the IAAS, which is being developed with the pilot's needs and desires taken into consideration, will

also decrease the workload for the tactical aircrew. This combination of ease of use and reducing overall workload is essential for all future systems.

C. OBJECTIVES OF HUMAN FACTORS

The objectives of any effective human factors program can be summarized as follows:

1. Improved human performance as shown by increased speed, accuracy, safety, and less energy expenditure and fatigue.
2. Less training and reduced costs.
3. Improved use of manpower through minimizing the need for special skills and attitudes.
4. Reduced loss of time and equipment as accidents due to human errors are minimized.
5. Improved comfort and acceptance by the user/operator. Human factors is concerned with improving the productivity of the operator by taking into account human characteristics in designing systems. [Ref. 4: p. 7]

D. HUMAN-MACHINE SYSTEMS

1. Definition

A system in the general sense is defined by Hall and Fagan as:

> A set of objects together with relationships between the objects and between their attributes. [Ref. 8]

The objects are components of the system. Systems occur within an environment and changes in the environment affect the system and its attributes. Systems are hierarchical in nature.

2. Types of Systems

Systems can be characterized by the degree of human versus machine control. There are basically three types of systems. They are (1) manual systems, (2) mechanical systems, and (3) automatic systems [Ref. 7: p. 11]. See Figure 1 on page 6 for an illustration of the three types of systems. Explanation of each of these follows.

a. Manual Systems

Manual systems consist of hand tools and other implements which are coupled together by the human operator who controls the operation, using his own physical energy as a power source. An example of a manual system would be a person operating a simple hand tool such as a hoe. The hoe extends the human's capability.

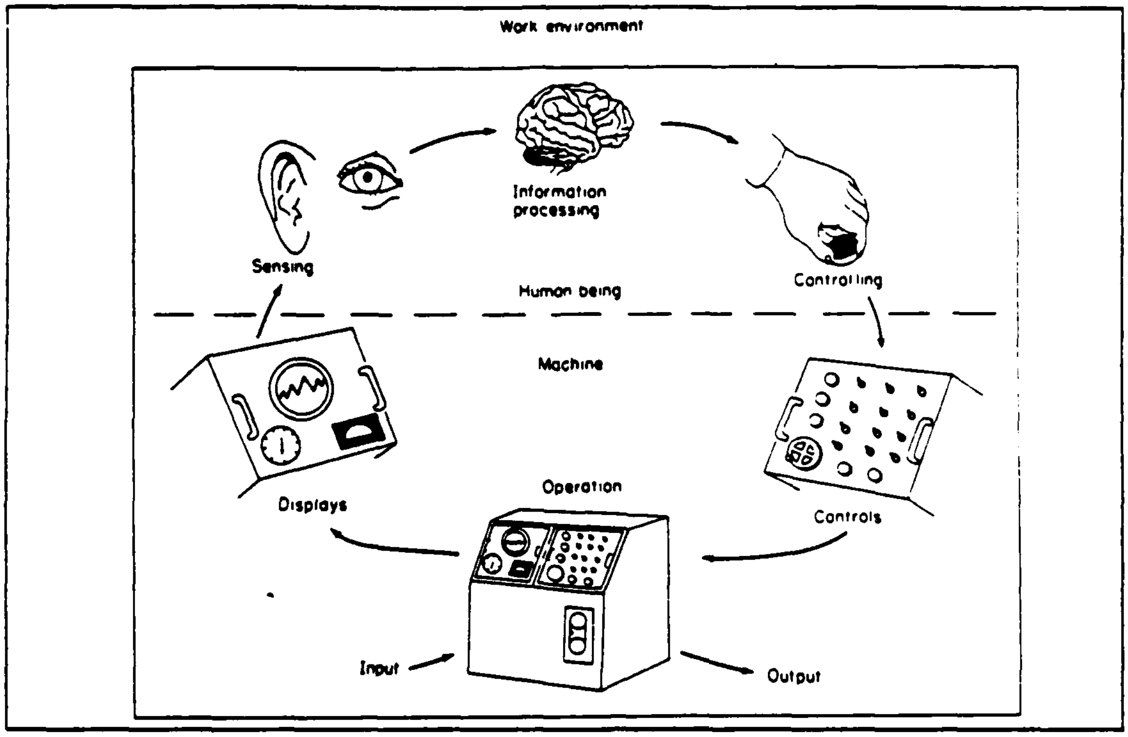


Figure 1. Human-Machine Systems. [Ref. 7: p. 14]

but the human provides both the power and the control. Feedback is received visually to permit altering movements appropriately.

b. Mechanical Systems

Complex machinery evolved following the industrial revolution. Instead of operators receiving information directly through their senses, devices were developed to sense changes in the environment or the machinery. An example of this would be a gasoline gauge or speedometer in an automobile. Instead of controlling the power source directly, the operator is given a number of control devices for controlling machine output. Unlike the person with the hoe, the machine provides the power to make the system move. These systems where the machine provides the power and the human provides control are semi-automatic systems.

c. Automatic Systems

The machine does both the sensing and the controlling as the standard operating procedure. The operator functions as a monitor entering the control loop to

override the automatic system and enter new data when required. The IAAS is an example of an automatic system where the pilot can set the level of automation required.

3. Characteristics of Human-Machine Systems

Systems have underlying characteristics. Six characteristics, as they relate to human-machine systems, have been described by Sanders and McCormick. [Ref. 7: pp. 14-17]

a. *Systems are Purposive*

All systems must have a purpose. They may have more than one and should include the goals and objectives of the system.

b. *Systems Can Be Hierarchical*

Systems can be segments of larger systems. Two decisions must be made to define a system. The boundary of the system must be determined, that is, what is inside the system and what is outside the system. It is up to the individual to define what is important. The second decision is where to set the limit of resolution for the system: how far down one goes to define the system. Again these limits are up to the individual.

c. *Systems Operate in an Environment*

The environment can be defined as everything outside the system. The environment can be extended to the general area or to the immediate area surrounding the system. Conditions in the environment may or may not affect the system.

d. *Components Serve as Functions*

The components, which are the lowest level of system analysis, serve to carry out the objectives of a system. Human factors specialists must decide whether man or machine will accomplish system functions. All components involve four basic functions, described as follows and shown graphically in Figure 2 on page 8.

1. *Sensing*: Sensing, or information receiving, can be received from either inside or outside the system. Information originating from inside the system can be either stored information or feedback.

2. *Information storage:* Information can be stored in physical components such as magnetic tapes and disks, records, and tables of data. For man, information is stored in the form of memory of learned material.

3. *Information processing and decision*: Where man is concerned information processing results in a decision to act or not to act. When machines are used the information processed by them must be programmed.

4. *Action functions:* These are generally the operations which occur as a result of the decisions that are made. These can be either physical control actions or communications actions.

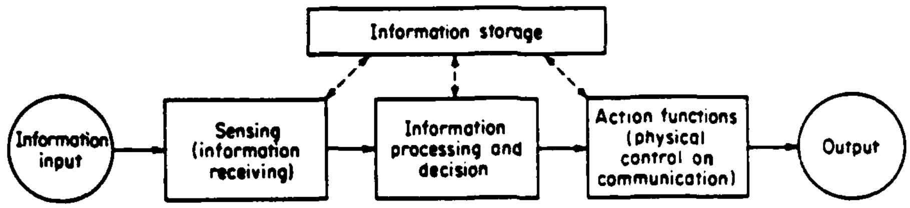


Figure 2. Functional Components of Human-Machine Systems. [Ref. 7: p. 16].

e. Components Interact

The components of the system work together to accomplish the system objectives. This interaction is integral to the working of the system as a whole.

f. Systems have Inputs and Outputs

This is true of all systems. The inputs to one system may be the outputs to another. It is through these channels that systems interact and communicate. Human factors specialists are called upon to determine the inputs and outputs necessary for the system to function successfully.

4. Systems Approach

In designing any new system, such as IAAS, many factors must be considered in addition to the hardware item itself. The systems approach takes into consideration where the system will be used, how and by whom it will be used, and what it must accomplish given certain limitations.

A systems approach involves a process of planning ahead to anticipate any problems. Therefore, from the initial conception of a system, the designer must begin planning for logistics, personnel requirements, job descriptions, training, and evaluation. Development of the best displays to facilitate ease of human use is extremely important. Once designed, cost and time involved can be too great to permit later redesign. [Ref. 4: p. 19]

III. THE INTELLIGENT AIR ATTACK SYSTEM

This chapter describes the Intelligent Air Attack System (IAAS) in terms of a number of characteristics. These include (1) a general description of the system, (2) the problems which prompted its development, (3) system concepts, functions, and requirements, and (4) system display formats. The display formats will form the basis for this study, in that the time-displayed tasks appear on the task agenda display format. The material for this chapter is adapted from selected NWC papers and technical reports [Refs. 1, 9 , 10].

A. GENERAL SYSTEM DESCRIPTION

The IAAS is a prototype software system in the advanced development phase designed for the Navy's F/A-18 aircraft. This system will help the aircraft crew by assisting with three essential tasks:

1. Classification of ship targets at long range
2. Evading or countering enemy missiles
3. Modifying and managing the strike plan during a mission [Ref. 10: p. 3]

IAAS will gather and correlate information from sensors to give the crew the most complete and current view of the world status. This system will format the gathered information after using a knowledge-based program to extract the specific information needed for current tasks. The format for these displays will be intuitively recognizable pictoral displays designed for rapid and accurate crew comprehension and response. [Ref. 1: p. 1]

B. PROBLEMS FACED BY AIRCREWS

By the 1990s the F/A-18 aircraft will have avionics capabilities which will exceed those of the present aircraft. New targeting and electronic warfare systems are being developed which will provide great amounts of information about "the status of the world". Aircrews will be called upon to carry out their missions in an environment which is already considered overloaded with tasks. Missions will be more complex because of the expected improved capabilities of potential adversaries. This "overload" condition is universal to all the services. [Ref. 9: p. 1]

Aircraft pilots must perform their tasks under conditions which can best be described as high-speed, low-level flight, with severe time compression. All these tasks

are completed while avoiding the adversarial threat. The specific problems facing tactical pilots can be summarized as follows:

1. Increased mental workload - both in the amount of information presented and increased decision complexity.
2. Increased manual workload - in operating the new systems. [Ref. 9: p. 1]

These problems increase the probability that the pilot will:

1. make the wrong decision or an incorrect response, because of not enough or too much information;
2. lose situational awareness, both of where he is in the mission and of where he is physically;
3. be unable to react fast enough; and
4. be unable effectively to juggle all the necessary tasks that must be completed. [Ref. 1: p. 2]

Despite all these problems, most aviators do not wish to place all their faith in automated systems. Pilots believe that missions and situations are all quite different and that computers systems are generally inflexible and not able to account for the differences effectively. The control of the aircraft must remain with the pilot. [Ref. 9: p. 2]

C. IAAS CONCEPTS

IAAS has been developed to help deal with the task and information overload facing the F/A-18 aircrew. More specifically, it will integrate three concepts related to knowledge-based computer systems and to human factors engineering. These are:

1. Adaptive automation
2. Intelligent information management
3. Status-at-glance displays [Ref. 10: pp. 3-5]

1. Adaptive Automation

Since there are a variety of mission tasks, various levels of automation will also be required. The pilot is able to chose the level of automation he desires based on the mission plan. The plan is customized on a task-by-task basis. The goal is to reduce workload without taking away the aircrew's ability to make decisions. This concept is illustrated in Figure 3 on page 11. The automation modes are described below: [Ref. 1: p. 2]

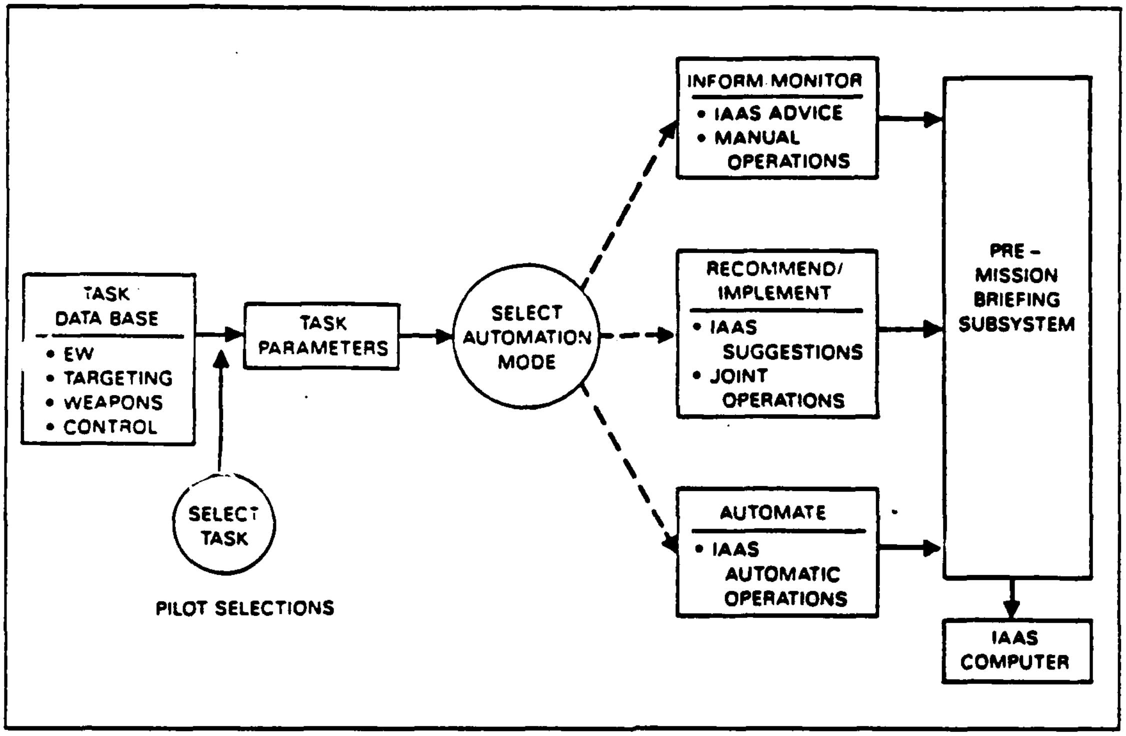


Figure 3. Adaptive Automation Concept. [Ref. 1: p. 4]

1. *Inform/monitor:* Information that is appropriate for the current tactical situation is provided. Any important events or deviations from the plan are also made apparent to the pilot.

2. *Recommend/implement:* The current tactical situation is made known. A menu of options and recommended actions are displayed. The pilot may concur with the recommended option and IAAS carries out the task, or he may select another option and execute the task himself.

3. *Automate:* IAAS initiates and carries out a task automatically when conditions which have been preselected have been met. [Ref. 1: p. 2]

2. Intelligent Information Management

The IAAS will collect and integrate prebriefed mission data and mission plans with the real-time data obtained by sensors and with pilot actions during the mission. The pilot is assured of receiving the most current and accurate information available, without unnecessary data which might overload his ability to make a decision. This concept is illustrated in Figure 4 on page 12.

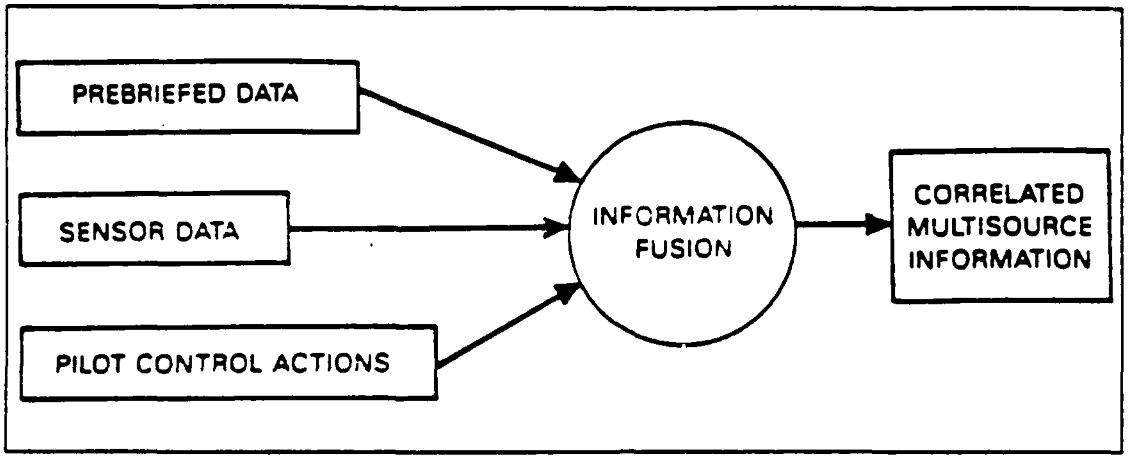


Figure 4. Intelligent Information Management Concept. [Ref. 1: p. 4]

3. Status-at-a-Glance Displays

The IAAS provides display formats which are designed for rapid mental processing. Rapid and correct pilot decisions are desired based on the intuitive comprehension of the current situation. This concept is illustrated in Figure 5 on page 13.

D. IAAS FUNCTIONS

IAAS will assist the aircrew by carrying out the following functions:

1. Premission briefing
2. Sensor data correlation and multisource information integration
3. Mission agenda management and task automation [Ref. 1: p. 5]

These are accomplished by three subsystems of IAAS.

1. Premission Briefing Subsystem

The IAAS Premission Briefing Subsystem (PMBS) provides premission briefing as it gathers and stores information required for a selected mission (see Figure 6 on page 14). Prior to take-off, this information is loaded into the computer from a prerecorded cartridge. Information which will be stored includes strike plan parameters (weapons, targets, route) and automation levels selected by the aircrew. [Ref. 1: p. 5]

2. Information Integration Subsystem

The IAAS Information Integration Subsystem (IIS) provides sensor data correlation and multisource information during the mission by continually pulling sensor

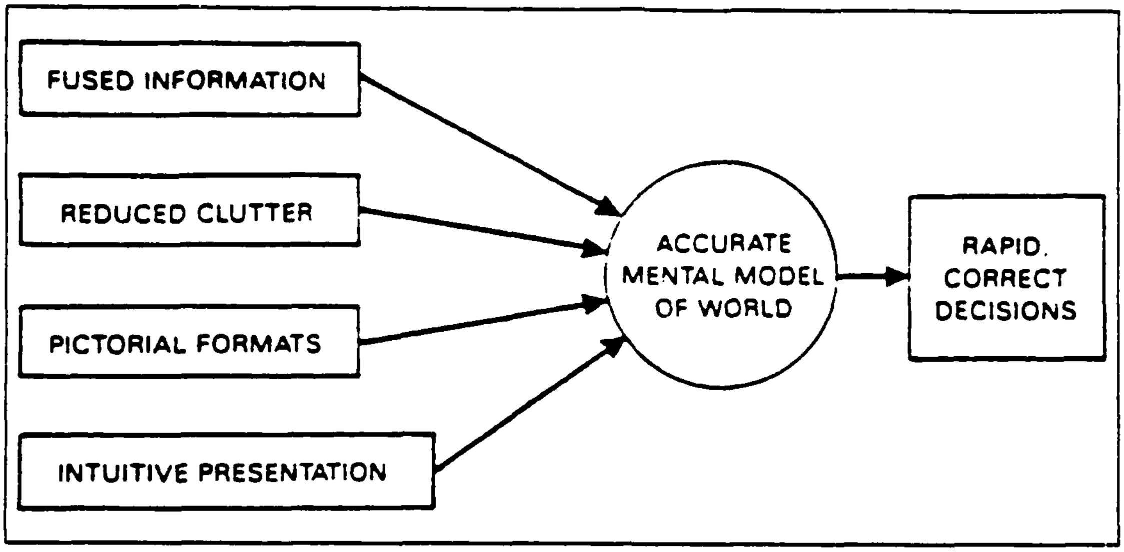


Figure 5. Status-at-a-Glance Displays Concept. [Ref. 1: p. 5]

data from preprocessors by means of a data bus (see Figure 7 on page 15). This subsystem will mesh this real-time data with that provided by PMBS to give a resulting current status of the world. The IIS utilizes a knowledge-based program to provide the crew with the specific information requested or required at that moment. This information is synthesized into an easily used and recognizable situation summary displayed for quick, accurate recognition and response.

3. Task Support Subsystem

The IAAS Task Support Subsystem (TSS) provides mission agenda management and task automation by keeping track of the progress of the mission agenda through the preprogrammed information and current information obtained from sensors. See Figure 8 on page 16 for an illustration of TSS. This subsystem also assists the pilot in completing required tasks by providing task support displays at the automation level preselected by the crew. [Ref. 1: p. 7]

E. IAAS REQUIREMENTS

There are basically five components that are required for full operation of the system. The interconnection of these components is shown in Figure 9 on page 17. A brief explanation of each component follows. [Ref. 1: pp. 8-9]

1. *A computer system*: An airborne computer capable of operating a knowledge-based software system is required for IAAS.

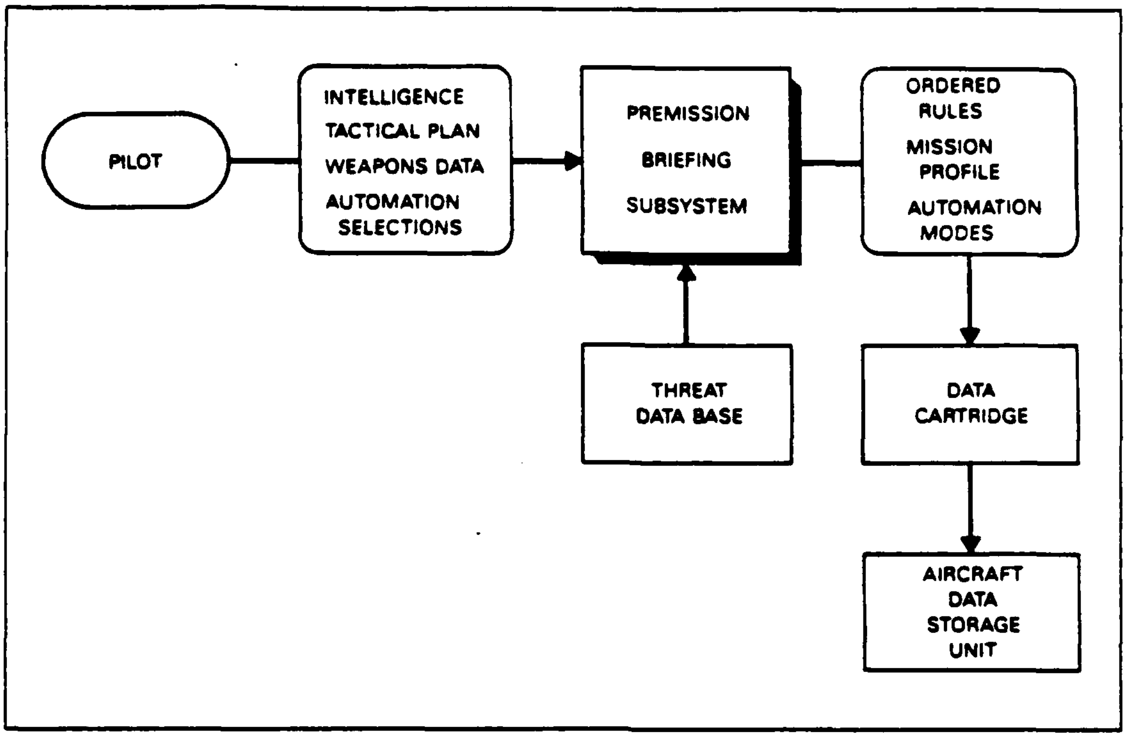


Figure 6. IAAS Premission Briefing Subsystem. [Ref. 1: p. 6]

2. *Prebriefing capability*: Prebriefing data will be entered via an aircraft mission loader from a cartridge or diskette. This would be prepared aboard the aircraft carrier prior to mission start.
3. *Onboard sensors*: Status information on what is operating in the area comes from electro-optical (E/O), electronic warfare (EW), and radar sensors. The knowledge-based systems must be able to synthesize all this data to come up with the best picture of the world status.
4. *Programmable multifunction displays and controls*: Displays using both head-up and head-down formats will be necessary for IAAS. Ease of pilot use is a primary consideration.
5. *Onboard communications links*: An avionics communications bus (MIL-STD-1553) will link various onboard sources to provide current information and send out queries and data.

F. IAAS DISPLAY FORMATS

Guidlines for optimum design of the human-computer interface have been followed in designing display formats for IAAS. They represent human factors principles that are intended for maximum ease of use and for rapid and precise decision making even under the worst conditions.

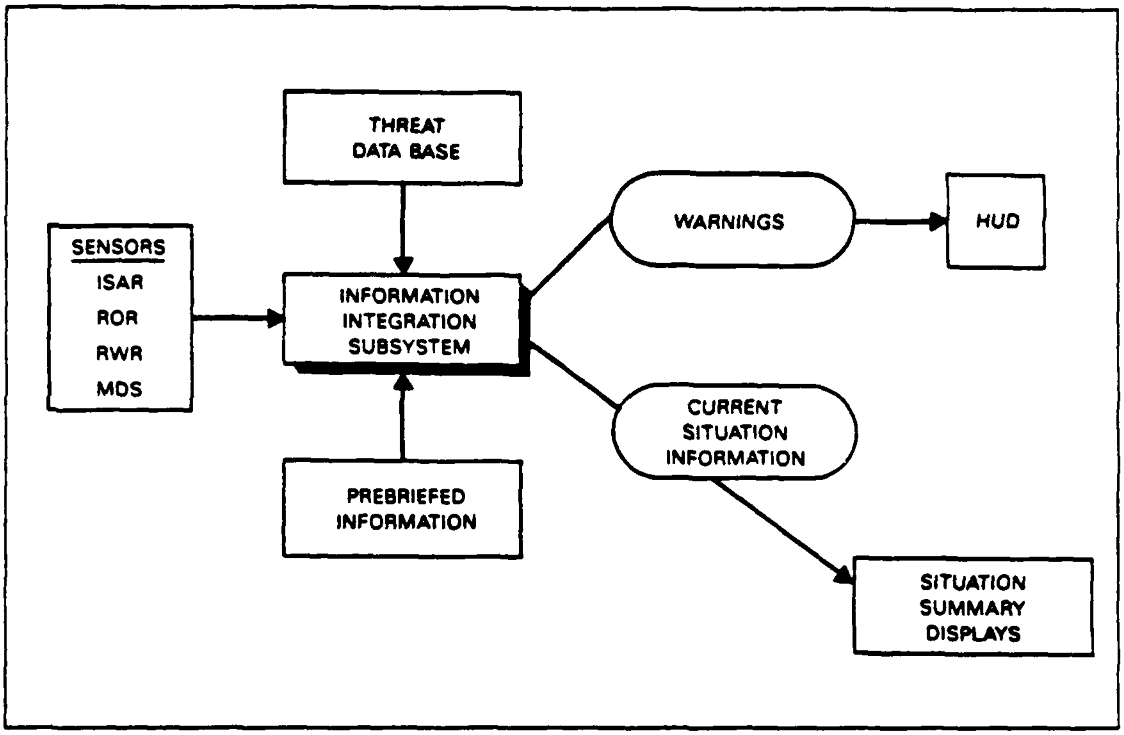


Figure 7. IAAS Information Integration Subsystem. [Ref. 1: p. 6]

All new IAAS displays will be cognitively compatible with existing displays in the F/A-18 aircraft. Making these displays compatible has been a consistent rule of thumb in the development of IAAS. Consistency has been chosen over possible preferred display practice in some instances.

For compatibility, the system designers have kept symbols, words, and phrases which already had definitions consistent in IAAS formats. Assignment location for information, and multifunction control assignments have also remained consistent with present practices. [Ref. 1 : p. 12]

IAAS does not replace any current F/A-18 functions and systems. It is intended to complement existing capabilities. The incorporation of IAAS into existing F/A-18 capabilities requires the design of several new display formats. These formats will either be monochrome as required for the present display, or full color, for displays which should be integrated into the F/A-18 in the near future [Ref. 1: p. 14]. A description of the display formats designed specifically for IAAS follows. [Ref. 1: pp. 14-17]

1. *Premission briefing display formats:* The formats which fall into this category are used for data entry into PMBS. These formats are presented prior to the start of

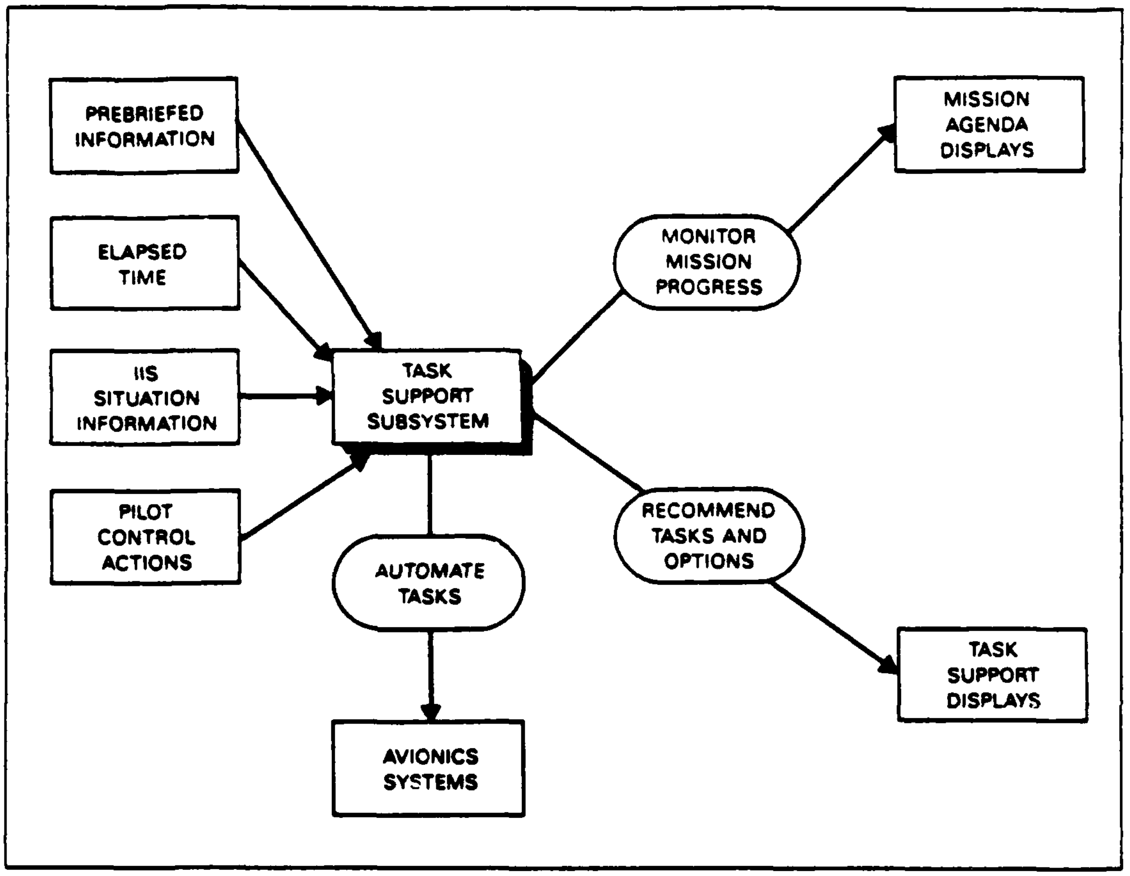


Figure 8. IAAS Task Support Subsystem. [Ref. 1: p. 7]

a mission on a standard IBM-compatible personal computer which is located on the aircraft carrier. Basically two kinds of data are entered: (1) strike plan parameters and (2) the selection of automation levels by the pilot.

2. *Head-up warnings and alerts:* These are vertical displays which provide symbols representing areas and objects that are correlated with the view out the windscreen.

3. *Situation summary display formats:* Compiled sensor and prebriefed information from IIS will create this display format. The format will be down-looking map-like summary displays.

4. *Task support display formats:* This format provides the pilot with some new capabilities. These are: (1) the ability to change his mission while it is in progress, (2) long-range ship identification, (3) ability to evade and counter enemy missiles, and (4) control selections to call IAAS functions. New display formats have been developed to support this.

5. *Agenda display format:* Information for this format is received from TSS which contains an agenda of mission tasks and expected mission events from both the premission briefing and its own knowledge (see Figure 10 on page 18). The agenda

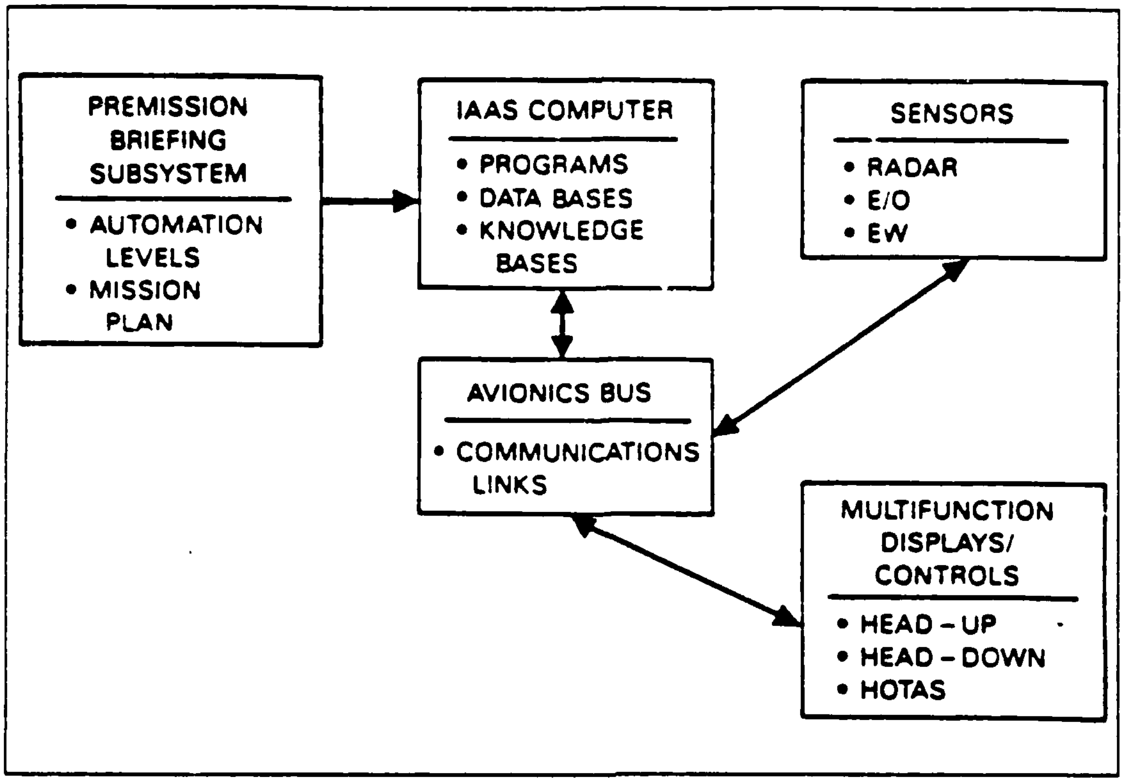


Figure 9. Basic Components Required for IAAS Operation. [Ref. 1: p. 8]

format resembles a time flow diagram. Currently, tasks and events move from left to right as the mission progresses. Agenda progress is determined by pilot action and a consecutive listing of events, not by the actual passage of time.

This study will concentrate on the agenda display formats. As mentioned, the display format is currently designed so that agenda tasks and events move in a "left to right" manner. This orientation was arbitrarily chosen by system designers. The logic in chosing this format was that of reading English text which is read from left-to-right. This study is designed to determine whether a mental model already exists for time-displayed tasks, and whether a better, or more intuitive, type of presentation could be used for these tasks.

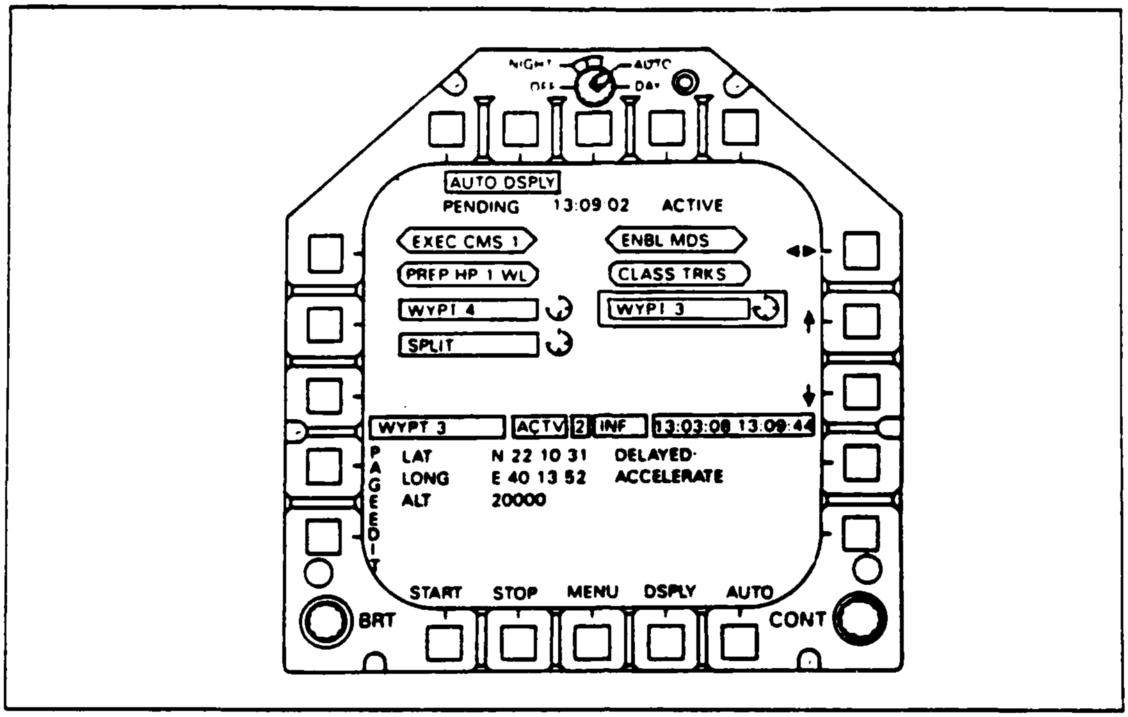


Figure 10. IAAS Agenda Display Format [Ref. 1: p. 17]

IV. NAVAL TELECOMMUNICATIONS SYSTEM APPLICATION

This chapter provides a general overview of the NTS. The need for a new time-related display format also is discussed.

A. MISSION

The mission of the NTS is to maintain and provide rapid, reliable, and secure transmissions of operational, tactical, and administrative information. This information is sent mainly in the form of written messages. The NTS is composed of a complex of systems, subsystems, and equipments that provides telecommunications networks for the operation, administration, and command and control of Navy resources. The shore-based communications components of the NTS are designed to fulfill this mission. [Ref. 11: p. 3-1]

B. NTS FUNCTIONS

The NTS is divided into four communication areas.

1. Atlantic
2. Mediterranean
3. Western Pacific
4. Eastern Pacific.

Each of these areas is composed of a variety of communications facilities including (1) area master station, (2) primary support communication station, (3) secondary support communication stations, and (4) special support communication facilities. [Ref. 11: p. IV-1]

1. *Area Master Station*: The Naval Communications Area Master Station (NAVCAMS) is the primary site for operational command authority for communications within each area. Numbered Fleet Commanders direct and control communications assets through the NAVCAMS.
2. *Primary support station*: Primary support stations are designated to carry out the minimum essential functions required in the event of a NAVCAMS failure. They also have the ability to supplement and extend the facilities of the NAVCAMS during heavy usage times and contingencies.
3. *Secondary support stations*: Secondary support stations provide limited communications coverage within a specified communications area. They can provide full period terminations which are dedicated continuously keyed circuits between ships and stations.

4. *Special support stations*: Special support stations provide indirect fleet support and are primarily responsible for enhancing operational and management requirements of shore based communications facilities.

C. NAVCOMPARS

Naval Communications Processing and Routing System (NAVCOMPARS) is a single integrated, automated system with the capability of providing communications interface with the NTS. Every NAVCAMS is responsible for fleet support in its area and is the primary keying station of the fleet broadcast. These functions are all handled automatically by NAVCOMPARS.

1. NAVCOMPARS Subsystems

NAVCOMPARS is functionally divided into nine related processing functions called subsystems. Each subsystem is executed by a separate software module that interfaces with the other subsystems. There are nine subsystems which carry out a variety of tasks, summarized as follows. [Ref. 12: pp. 65-74]

1. *Executive control subsystem*: This subsystem is designed to meet the interface requirements between software and hardware.
2. *Configuration management subsystem*: Controls all system management functions and handles the operator-to-NAVCOMPARS interactions.
3. *Communications control subsystem*: Initializes the system or controls restarts after system downtime. It also handles the logs that record the processing actions of NAVCOMPARS.
4. *Receive control subsystem*: Receives all the traffic from the input circuits. It assigns a reference number to the message which will be used by all the other subsystems. Records messages on two files for recovery purposes in the event of system failure.
5. *Message processing subsystem*: Performs message analysis, message format conversions, VDT interface, removes duplicate messages in the system, performs internal distribution for over-the-counter customers, and writes the messages to a storage disk.
6. *Transmission processing subsystem*: Queues the messages to the appropriate output channel in precedence order. Maintains several directories.
7. *Transmission control subsystem*: Works together with the Transmission processing subsystem to initiate and terminate message transmissions. Ensures delivery to the proper output channel.
8. *Support program subsystem*: Generates all off-line reports mainly used for traffic analysis.
9. *System service subsystem*: Performs disk and magnetic file initialization, maintenance of files, and access to storage files.

2. Message Flow and Queues

Message flow within the NAVCOMPARS system does not involve all of the subsystems. The actual pattern for message flow is shown in Figure 11 on page 22. Messages arrive on various input circuits and are received, filed, and assigned a processing sequence number by the Receive Control Subsystem. The Receive Control Subsystem transfers the message to the Message Processing Subsystem for processing. It is filed on a storage disk, then sent to the Transmission Processing Subsystem for delivery. The Transmission Processing Subsystem queues the messages by precedence order for transmission on an output circuit.

Operators at VDTs located within a message center are able to "call up" messages by precedence order and see how long they have been in the queue. Having a display format which would facilitate rapid mental processing of the information displayed would be beneficial to the operators.

The NAVCOMPARS system has the capability to handle the message processing queues that develop. As messages are processed by NAVCOMPARS subsystems, messages are transferred from queue to queue. Although the system has been able to handle the ever-increasing message volume, there is a limit to this system's capability.

D. TRAFFIC MANAGEMENT PROBLEMS

Over the past ten years message volume has increased at a rate of 6% per year [Ref. 13: p. 1-2]. The length of messages has also increased. The NTS network has become increasingly overloaded. The NAVCOMPARS system is impacted greatly by this trend due to the relatively slow transmission rate of some of the circuits that feed into the system (75 baud fleet broadcast). The queues can be expected to get longer and more unmanageable if the current growth in message volume continues.

Having computer display formats which will provide information which can be rapidly processed would help this problem. System operators would be able to scan the screen quickly to see which messages need immediate action for delivery within the maximum allowed time, especially when the system is operating at full capacity.

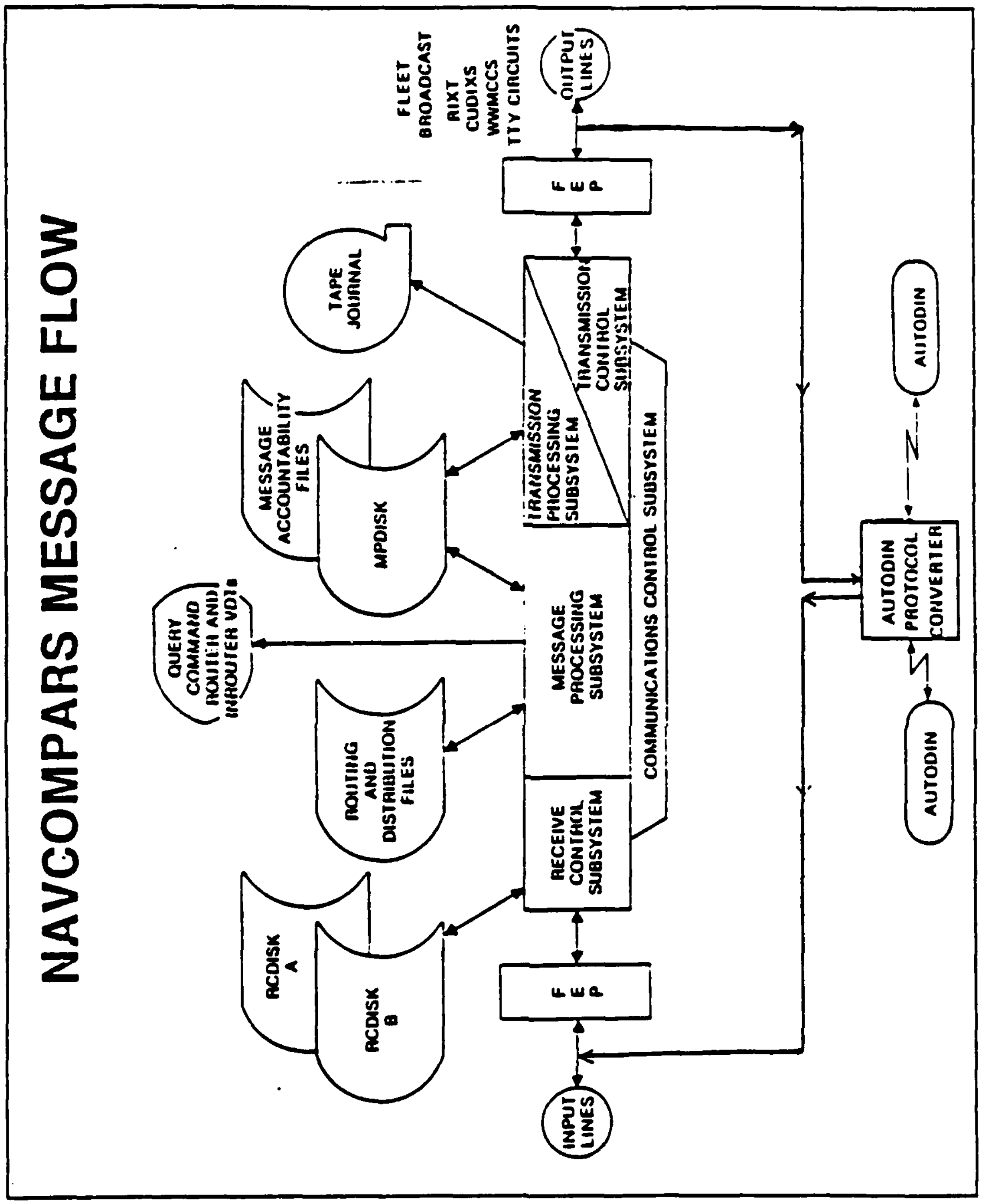


Figure 11. NAVCOMPARS Message Flow. [Ref. 12: p. 72]

V. APPROACH AND METHODOLOGY

A. APPROACH

Data were collected for this study via a survey given to three groups of military officers. The survey consisted of 12 questions (see Appendix). The first 11 questions were designed to obtain background information on the people taking the survey. The twelfth question has six parts, each part describing a different scenario relating some aspect of time to the presented situation.

The first group was used to test the questionnaire for ambiguities and general clarity. The survey was revised based on comments made by that initial group. The revised survey then was administered to the other two groups.

B. STUDY PARTICIPANTS

1. Group One

The eight participants in the initial survey are all masters degree candidates at Naval Postgraduate School (NPS), Monterey, CA. This group was asked to respond to the questions and also to check them for general clarity. Five members of this group are males studying Anti-Submarine Warfare. The other three, two males and one female, are students in the Strategic Planning Curriculum of the National Security Affairs Department.

2. Group Two

The 29 participants, 21 males and eight females, in the second group are also masters degree candidates at NPS. The group was divided among three curricula: Telecommunications Systems Management, Computer Science, and Computer Systems Management.

3. Group Three

The 11 participants (all males) in the third group were students in the Aviation Safety Officers School at NPS. This group was selected because all of the participants are military aviators, either pilots or navigators. Both aviation experience and familiarity with cockpit displays made their opinions valuable for this study.

C. SURVEY DESCRIPTION

The survey was developed as a means to determine whether there is a mental model for time. The first seven questions were designed to obtain information about the

participants' experience and orientation in the service. The next four questions asked for educational background and military experience, information used to determine whether educational domain and job experience contribute to perception of time.

Six time related scenarios were provided next in the survey. The first four describe simple situations which had been experienced by everyone in the sample groups. The first, concerning studying for a history exam, sought to relate an early learning experience to placing events in time sequence.

The second and third scenarios represent real situations experienced quarterly by all NPS students. Each student receives a class schedule form and also a card on which to annotate his or her location each hour during the week (locator card). Class schedules list the days of the week along the left margin; class periods, which correspond to hours of the day, are listed across the top. Class locator cards, on the other hand, list the class hours along the left margin and the days of the week across the top. These scenarios demonstrate that identical information can be presented in completely different formats. The participants were asked to indicate how they would rate these two designs along a scale which ranged from "very logical" to "very illogical".

The fourth scenario was included to test how mental models of time are influenced by the convention that time is represented horizontally on graphs as the independent variable; that is, on the x axis. Axes (x and y) were presented graphically, and participants were asked to indicate on which axis they would display time.

The final two scenarios are more complex, representing a telecommunications example and a tactical air situation, both time related. In each case the participants were asked to review the situation and decide which display format would provide them with the information they need, with the greatest ease. The following choices were listed.

1. Top-to bottom
2. Bottom-to-top
3. Right-to-left
4. Left-to-right
5. Back-to-front
6. Front-to-back.

The telecommunications scenario was included as a military application where time is a critical variable. In this system, (described in Chapter IV), incoming messages are received, assigned a sequence number, stored, and queued for processing. Messages are processed from the queue by precedence. In the scenario, the maximum time allowed

for delivery of each message for the different precedences is given. The study participants were asked to choose the display which would best illustrate both the time in queue and the urgency for delivery. This situation is familiar to communications specialists, and the type of system described does exist.

The F/A-18 tactical air scenario is a hypothetical situation based on a possible air-to-surface attack mission. This scenario applies to a 1990-configured F/A-18 aircraft using HARM and Harpoon weapons, in a war-at-sea mission. Events of the type described in this scenario would be programmed into IAAS for display to the pilot during the mission. The results of this question would be directly applicable to the system under development for the F/A-18 aircraft.

D. SURVEY PROCEDURE

The survey was given in a classroom environment in three separate sessions. The survey was handed out in its entirety and participants were permitted to ask questions at any time. The survey took approximately 15 minutes to complete.

Most of the questions asked by participants concerned the last two scenarios. Initial wording of these scenarios led the participants in the first group to think about actually designing the display format, instead of merely providing their own mental model for the situation. The questions were rewritten for groups two and three so that the conceptual design rather than the actual physical display was considered.

VI. DATA ANALYSIS

A. BACKGROUND INFORMATION CONCERNING PARTICIPANTS

Background information on each of the groups who participated in the survey is summarized in the following sections.

Table 1 shows the number of participants in each survey group and the breakdown by age for the three groups.

Table 1. AGE OF PARTICIPANTS

	Group Size	Range	Mean
Group One	8	27-38	30.6
Group Two	29	27-36	30.4
Group Three	11	27-34	30.6
Total Participants	48	-	-

Table 2 shows the breakdown by number of years in service for the three survey groups.

Table 2. YEARS IN SERVICE

	Group Size	Range	Mean
Group One	8	4-13	7.6
Group Two	29	3-15	8.2
Group Three	11	5-13	8.5
Total Participants	48	-	-

Table 3 on page 27 shows the breakdown by undergraduate educational background for the three survey groups.

Table 3. EDUCATIONAL BACKGROUND

	Technical	Non-Technical
Group One	7	1
Group Two	20	9
Group Three	6	5
Total Participants	33	15

Table 4 on page 28 shows the breakdown by designator (Naval officers) and military occupational specialty (MOS) (Marine Corps officers) for participants in the three survey groups.

Table 4. DESIGNATOR/MOS

Group One			
Designator:			
	Surface (1110)		3
	Aviation:		
		NFO (1320)	1
	Submarine (1120)		3
	General Unrestricted Line (1100)		1
Group Two			
Designator:			
	Surface (1110)		8
	Aviation:		
		NFO (1320)	3
		Pilot (1310)	3
	GURL (1100)		7
	Cryptology (1610)		1
	Intelligence (1630)		1
MOS:			
	Aviation (7562)		1
	Logistics Support (4002)		2
	Supply (3002)		1
	Communications (2502)		1
	Artillery (0802)		1
Group Three			
Designator:			
	Aviation:		
		NFO (1320)	1
		Pilot (1310)	5
MOS:			
	Aviation:		
		Pilot	5

1. Analysis of Group One Participants

Most of the male participants in this group are on their first shore assignment following an initial division officer sea tour. The other males are on second shore

assignments following a department head at-sea assignment. The female participant has always been on shore assignments and has completed several division officer tours.

The participants' designators represent all the unrestricted line communities. All of the males indicate that their undergraduate degrees were in technical fields. Although the female indicated that her degree was non-technical all her assignments have been in technical areas.

2. Analysis of Group Two Participants

The characteristics for Group Two are similar to those of Group One for the students in the Navy. However, one of the women is a surface line officer (1110). The restricted line communities of cryptology (1610) and intelligence (1630) are also represented.

Most of the participants consider their education technical. Those who stated their education was non-technical have held "technical" jobs in the Navy. This is very common, since most jobs in the Navy require technical expertise in some area. Officers gain this "technical" knowledge in service schools or on the job.

The Marine Corps officers in this group represent the logistics support (4002), supply (3002), aviation (7562), artillery (0802), and communications (2502) military occupational specialties (MOS). They have had typical careers for their particular specialties. All Marine Corps officers in this group consider their educational background technical.

3. Analysis of Group Three Participants

The characteristics for this group of officers is different from the other two groups: all are aviators, either pilots or navigators. The students who are Naval officers are either division officers or department heads in an aviation squadron. The educational background of the group is almost evenly split between technical and non-technical. The service schools attended plus the jobs held by these officers, however, have been in technical areas.

B. ANALYSIS OF SCENARIO RESULTS

1. History Exam

This question asked how events in chronological order are best learned. The results, with the number of participants who selected each choice, are shown in Table 5 on page 30.

Table 5. HISTORY EXAM SCENARIO RESULTS

	Horizontally		Vertically	
Group One	1	(12.5%)	7	(87.5%)
Group Two	3	(10.3%)	26	(89.7%)
Group Three	5	(45.5%)	6	(54.5%)
Total Participants	9	(19%)	39	(81%)

Clearly, the participants in Groups One and Two regard learning a chronological list of events in a vertical manner to be the best. Many reference books print historical time-ordered events horizontally on a time-line, which makes these results surprising. Survey participants in these two groups chose the vertical presentation 87.5% and 89.7%, respectively, as the best for giving the sense of chronological order, while 54.5% of Group Three selected the vertical presentation. The wording of the question may have contributed to these results since participants were asked how they would "list" the battles. A "list" is usually a vertical ordering of some group of items.

2. Class Schedules/Class Locator Cards

The manner in which time is displayed on these two kinds of schedule cards is exactly opposite. This question was designed to determine whether one presentation was preferable to the other. The results with the number of participants who selected each choice are shown in Table 6 on page 31.

Table 6. CLASS SCHEDULE/CLASS LOCATOR CARD RESULTS

	Logical	Illogical
Group One:		
Class Schedules	2 (25%)	6 (75%)
Class Locator Cards	6 (75%)	2 (25%)
Group Two:		
Class Schedules	9 (31.1%)	20 (68.9%)
Class Locator Cards	20 (68.9%)	9 (31.1%)
Group Three:		
Class Schedules	6 (54.5%)	5 (45.5%)
Class Locator Cards	10 (90.9%)	1 (9.1%)
Total Participants		
Class Schedules	17 (35.4%)	31 (64.6%)
Class Locator Cards	36 (75%)	12 (25%)

The results indicate that these scheduling items are perceived to be contrary to each other by the first two groups, and one is definitely preferable to the other. The calendar-like class locator card format is preferred to the class schedule by each group: 75%, 68.9%, and 90.9%, respectively. The same individuals in Groups One and Two who chose the class schedule as logical also chose the class locator card as illogical. The reason given was that time should be displayed horizontally, which makes the class schedule preferable.

The third group did not follow the same pattern. Their selections are not mirror images of each other as are the selections made by the first two groups. Aviation Safety School students do not have the familiarity with these two items that NPS students have each quarter. This may have contributed to the apparent independence of their choices. The reason given by all those who chose the class locator card as more logical was that it resembled a calendar and was , therefore, more familiar.

3. Time Axis Graph

The x axis was chosen universally by all groups as the axis on which to display time. Some of the reasons given for this choice follow:

- Time is horizontal.
- Time is the independent variable, and is, therefore, displayed on the x axis.
- Time moves in a horizontal left-to-right manner.
- It's tradition.
- A time-line should move left-to-right like a number line.

Educational bias appears to influence this choice. Time, by convention, is almost universally placed on the x axis. Also, since the participants have overwhelmingly technical backgrounds, these results indicate familiarity with graphical representations of change versus time.

4. Telecommunications Scenario

The results of participants' responses concerning the telecommunications scenario are summarized in Tables 7, 8, and 9 for the three individual groups, and Table 10 for the study participants as whole.

a. Results by Survey Group

For Group One, the front-to-back format was ranked first by 50% of the participants, followed by top-to-bottom (25%), left-to-right (12.5%) and bottom-to-top (12.5). Right-to-left and back-to front received no first place rankings.

For Group Two, the front-to-back format was again selected most frequently (50%), followed by left-to-right (31%) and top-to-bottom. Bottom-to-top and right-to-left did not receive any first place rankings.

For Group Three, the front-to-back format was ranked first by 45% of the participants, followed by left-to-right (18%), top-to-bottom (18%), and back-to-front (18%). Bottom-to top and right-to-left received no first place rankings.

When results from all three groups are combined, it can be seen that the front-to-back format is clearly considered the best information storage schema for the telecommunications scenario (48%). Left-to-right received the next highest number of first place rankings (25%), and top-to-bottom came in third (17%). Results of analysis of first place rankings was sufficiently clear cut that no attempt was made to perform additional analyses on these data values.

b. Comments by the participants

Some of the comments made by participants follow.

- For the telecommunications scenario, one would mainly be interested in the highest priority traffic; therefore, the ability to scan ahead would not be critical.
- It is natural to recognize things in a left-to-right manner. It takes a few seconds more if things are in a different order and also allows for the possibility of reversing the intended order.
- A display which requires the least head and eye movement is best. In our culture, we tend to go from left-to-right and from top-to-bottom. It is easier for people to absorb information following this scheme.

The participants were able to grasp the conceptual difference between the telecommunications scenario and the air scenario. Delivery of message traffic is time critical. Knowing which messages require immediate attention is important. The selection of the front-to-back presentation is not unexpected. This presentation would only show the most pressing events (highest priority message delivery) which would require ones' attention. At the same time, it also shows that there are other messages waiting delivery, but they do not crowd the viewer's field of view with unnecessary information.

Table 7. TELECOMMUNICATIONS SCENARIO RESULTS, GROUP ONE

Front-to-Back		
Rank	Frequency	Rel. Frequency
1	4	.50
2	1	.125
3	2	.25
4	0	.0
5	0	.0
6	1	.125
Back-to-Front		
1	0	.0
2	0	.0
3	1	.125
4	3	.375
5	0	.0
6	4	.50
Left-to-Right		
1	1	.125
2	2	.25
3	4	.50
4	1	.125
5	0	.0
6	0	.0
Right-to-Left		
1	0	.0
2	0	.0
3	0	.0
4	2	.25
5	3	.375
6	3	.375
Top-to-Bottom		
1	2	.25
2	5	.625
3	1	.125
4	0	.0
5	0	.0
6	0	.0
Bottom-to-Top		
1	1	.125
2	0	.0
3	0	.0
4	2	.25
5	5	.625
6	0	.0

Table 8. TELECOMMUNICATIONS SCENARIO RESULTS, GROUP TWO

Front-to-Back		
Rank	Frequency	Rel. Frequency
1	14	.48
2	7	.24
3	5	.17
4	0	.0
5	3	.10
6	0	.0
Back-to-Front		
1	2	.07
2	4	.14
3	2	.07
4	3	.10
5	3	.10
6	15	.52
Left-to-Right		
1	9	.31
2	8	.28
3	8	.28
4	0	.0
5	2	.07
6	2	.07
Right-to-Left		
1	0	.0
2	3	.10
3	0	.0
4	7	.24
5	11	.38
6	8	.28
Top-to-Bottom		
1	4	.14
2	10	.34
3	11	.38
4	4	.14
5	0	.0
6	0	.0
Bottom-to-Top		
1	0	.0
2	2	.07
3	2	.07
4	13	.45
5	7	.24
6	5	.17

Table 9. TELECOMMUNICATIONS SCENARIO RESULTS, GROUP THREE

Rank	Frequency	Rel. Frequency
Front-to-Back		
1	5	.45
2	3	.27
3	3	.27
4	0	.0
5	0	.0
6	0	.0
Back-to-Front		
1	2	.18
2	0	.0
3	0	.27
4	3	.27
5	1	.09
6	5	.45
Left-to-Right		
1	2	.18
2	1	.09
3	3	.27
4	3	.27
5	2	.18
6	0	.0
Right-to-Left		
1	0	.0
2	1	.09
3	0	.0
4	3	.27
5	3	.27
6	4	.36
Top-to-Bottom		
1	2	.18
2	6	.55
3	1	.09
4	1	.09
5	0	.0
6	1	.09
Bottom-to-Top		
1	0	.0
2	0	.0
3	4	.36
4	1	.09
5	5	.45
6	1	.09

Table 10. TELECOMMUNICATIONS SCENARIO RESULTS, COMBINED

Rank	Frequency	Rel. Frequency
Front-to-Back		
1	23	.48
2	11	.23
3	10	.21
4	0	.0
5	3	.06
6	1	.02
Back-to-Front		
1	4	.08
2	4	.08
3	3	.06
4	9	.19
5	4	.08
6	24	.50
Left-to-Right		
1	12	.25
2	11	.23
3	15	.31
4	4	.08
5	4	.08
6	2	.04
Right-to-Left		
1	0	.0
2	4	.08
3	0	.0
4	12	.25
5	17	.35
6	15	.31
Top-to-Bottom		
1	8	.17
2	21	.44
3	13	.27
4	5	.10
5	0	.0
6	1	.02
Bottom-to-Top		
1	1	.02
2	2	.04
3	6	.125
4	16	.33
5	17	.35
6	6	.125

5. Air Scenario

The results of the air scenario are summarized in Tables 11, 12, and 13 for the individual survey groups and in Table 14 for study participants as a whole.

a. *Results by Survey Group*

For Group One, the top-to-bottom format was ranked in first place by 50% of the participants, followed by, left-to-right (25%), and front-to-back (12.5%) and bottom-to-top (12.5%). Right-to-left and back-to-front received no first place rankings.

For Group Two, the top-to-bottom format was ranked first by 38% of the participants, followed by front-to-back (34%), and left-to-right (17%). None of the other formats received any first place rankings.

For Group Three, the left-to-right format was ranked first by 36% of the participants, followed by top-to-bottom (27%), front-to-back (18%), and back-to-front (18%). This is interesting in that this group contained all the aviators, and they selected a different format than did the other two groups. Right-to-left and bottom-to-top received no first place rankings from the aviators.

When results from all three groups are combined, it can be seen that the top-to-bottom format is clearly considered the best information storage schema for the tactical air scenario (37.5%). Front-to-back received the next highest number of first place rankings (27%), and left-to-right came in third (23%). Results of analysis of first place rankings was sufficiently clear cut that no attempt was made to perform additional analyses on these data values.

b. *Comments by participants*

Some of the comments made by participants follow.

- Schemes where operators can scan ahead allow them to anticipate what is coming next. Anticipation is a key to good operator performance.
- The most pivotal action in the "strike" may be a later event, but one would want this task in the front of one's mind. The ability to see some of the upcoming events would make this apparent.
- The highest priority event will probably be associated with the hardware structure such that when a scan takes place the aviator will associate where to look for information with the structure of his instrument panel (i.e., would look for the next event to be bordered by the edge of the CRT screen whether it be top-to-bottom or left-to right).
- Top-to-bottom is preferred to left-to-right (as I chose in the telecommunications scenario) since physical action is required rather than just viewing.

- It seems more natural to arrange the information in such a way as to orient it towards the top left of the screen, as that is where we look first when reading a book, using a computer, etc.. This is conditioned from early childhood.
- For cockpit displays (especially HUDs) the progression is more comfortable with simple, uncluttered data segments to allow for scanning while performing mission requirements. Integrated profile displays (left-to-right and front-to-back) work best for me.
- Right-to-left, bottom-to-top, and back-to-front seem very illogical, to the point of being detrimental. People naturally read left-to-right, so this seems to be the most logical. Front-to-back would be too slow, and would not allow you to anticipate actions.
- The best format for me would be a circular ring with events/actions moving up to the 12 o'clock position as they become current, and disappearing as action takes place or time expires.

The importance of knowing what event will happen next or having the ability to anticipate an event is clearly seen as an important factor. Thus, any presentation which indicates the current plus future events is desirable. The top-to-bottom display is favored by the combined survey participants, although the left-to-right and bottom-to-top presentations are also acceptable.

Another possible alternative for this display format is the circular ring suggested by one of the survey participants. This format was not examined in this study. It is, however, an interesting alternative which may warrant further investigation.

Table 11. AIR SCENARIO RESULTS. GROUP ONE

Front-to-Back

Rank	Frequency	Rel. Frequency
1	1	.125
2	2	.25
3	3	.375
4	0	.0
5	2	.25
6	0	.0

Back-to-Front

Rank	Frequency	Rel. Frequency
1	0	.0
2	0	.0
3	0	.0
4	4	.50
5	0	.0
6	4	.50

Left-to-Right

Rank	Frequency	Rel. Frequency
1	2	.25
2	5	.625
3	0	.0
4	0	.0
5	0	.0
6	1	.125

Right-to-Left

Rank	Frequency	Rel. Frequency
1	0	.0
2	0	.0
3	1	.125
4	1	.125
5	3	.375
6	3	.375

Top-to-Bottom

Rank	Frequency	Rel. Frequency
1	4	.50
2	2	.25
3	2	.25
4	0	.0
5	0	.0
6	0	.0

Bottom-to-Top

Rank	Frequency	Rel. Frequency
1	1	.125
2	0	.0
3	0	.0
4	3	.375
5	3	.375
6	0	.0

Table 12. AIR SCENARIO RESULTS, GROUP TWO

Rank	Frequency	Rel. Frequency
Front-to-Back		
1	10	.34
2	6	.21
3	9	.31
4	1	.03
5	3	.10
6	0	.0
Back-to-Front		
1	0	.0
2	0	.0
3	2	.07
4	5	.17
5	3	.10
6	19	.66
Left-to-Right		
1	5	.17
2	5	.17
3	14	.48
4	2	.07
5	3	.10
6	0	.0
Right-to-Left		
1	0	.0
2	1	.03
3	1	.03
4	9	.31
5	7	.24
6	11	.38
Top-to-Bottom		
1	11	.38
2	14	.25
3	4	.14
4	0	.0
5	0	.0
6	0	.0
Bottom-to-Top		
1	0	.0
2	0	.0
3	4	.14
4	8	.28
5	12	.41
6	5	.17

Table 13. AIR SCENARIO RESULTS, GROUP THREE

Front-to-Back

Rank	Frequency	Rel. Frequency
1	2	.18
2	5	.45
3	4	.36
4	0	.0
5	0	.0
6	0	.0

Back-to-Front

Rank	Frequency	Rel. Frequency
1	2	.18
2	0	.0
3	0	.0
4	0	.0
5	3	.27
6	6	.55

Left-to-Right

Rank	Frequency	Rel. Frequency
1	4	.36
2	1	.09
3	5	.45
4	0	.0
5	1	.09
6	0	.0

Right-to-Left

Rank	Frequency	Rel. Frequency
1	0	.0
2	0	.0
3	0	.0
4	4	.36
5	2	.18
6	5	.45

Top-to-Bottom

Rank	Frequency	Rel. Frequency
1	3	.27
2	5	.45
3	2	.18
4	1	.09
5	0	.0
6	0	.0

Bottom-to-Top

Rank	Frequency	Rel. Frequency
1	0	.0
2	0	.0
3	0	.0
4	6	.55
5	5	.45
6	0	.0

Table 14. AIR SCENARIO RESULTS, COMBINED

Rank	Frequency	Rel. Frequency
Front-to-Back		
1	13	.27
2	13	.27
3	16	.33
4	1	.02
5	5	.0
6	0	.0
Back-to-Front		
1	2	.04
2	0	.0
3	2	.04
4	9	.19
5	6	.125
6	29	.60
Left-to-Right		
1	11	.23
2	11	.23
3	19	.40
4	2	.04
5	4	.08
6	1	.02
Right-to-Left		
1	0	.0
2	1	.02
3	2	.04
4	14	.29
5	12	.25
6	19	.40
Top-to-Bottom		
1	18	.375
2	21	.44
3	8	.17
4	1	.02
5	0	.0
6	0	.0
Bottom-to-Top		
1	2	.04
2	0	.0
3	4	.08
4	17	.35
5	20	.42
6	5	.10

VII. CONCLUSIONS AND RECOMMENDATIONS

The information presented in this study demonstrates that individuals have certain conceptual ideas about time. These time-related mental models are not constant, but rather appear to vary depending on the task that is envisioned or being performed. Conclusions and recommendations are necessarily preliminary since they are based on a relatively small sample size. However, even though the groups were small, basic ideas about mental models related to time were repeated by each group, and are worth noting.

A. CONCLUSIONS

The following preliminary conclusions may be drawn from data gathered during this study.

- It is possible to develop a survey which elicits thinking about time-ordered events.
- Participants felt that events which are listed chronologically are best learned in a vertical rather than horizontal listing.
- Schedules which display events occurring at a specific time and day are most logically presented like a calendar, with the days of the week across the top and time of day along the side.
- Time is seen as being placed on the *x axis* of a graphical representation, by convention.
- For events which are time critical, displaying the highest priority item is most important and should be the most apparent in the display format.
- For events which have a specific time order, the ability to anticipate the next event is important.

B. RECOMMENDATIONS

Based on the conclusions drawn from this study, the following recommendations are made.

- This survey should be given to a larger group, to develop more conclusive trends related to mental models of time.
- For a communications application, where timeliness is critical to successful operation, a front-to-back display format is recommended for time-related objects or events.
- For an aircraft crew station application, where events are time-ordered and the ability to anticipate what event happens next is important, the top-to-bottom display of time-related events and tasks is recommended.

- Since the aviators who were surveyed preferred the left-to-right display for the aircraft crew station application, testing another group of aviators is recommended to see if this trend is consistent.

- Other time-related display formats should be considered for further studies, including a circular clock-like representation proposed by one participant in this study.

APPENDIX SURVEY FORM

This survey is being conducted as part of a study which will assist in determining a display format for time-dependent tasks in the F/A-18 cockpit. This is a human factors-based study which means that ease of use for the pilot will be a major consideration. However, when answering questions which pertain to time-based scenarios, rank the alternatives in the order which you would prefer.

1. Name: ______________________________

2. Age: ______ 3. Sex: M or F 4. Rank: __________

5. Branch of Service: _____ 6. Designator/MOS: _____

7. Years in Service: _____

8. Undergraduate Degree: ______________________

9. Would you describe your education as *technical* or *non-technical*? ______________________

10. What are you studying at NPS? ______________

11. Service Experience

List duty stations and billets:

____

____

____

12. Scenarios:

A. Imagine you are studying for a history exam. You must learn all the major battles which occurred during the Civil War. How would you list these battles to help you learn their chronological order?

_______ Horizontally, as on a time-line

_______ Vertically

_______ Some other way (please explain)

B. Class schedules are distributed at NPS in the following format:

	PERIOD				
	1	2	3	4	5
Monday					
Tuesday					
Wednesday					
Thursday					
Friday					

How logical does this seem to you? (use the following LogicMeter)

Very Logical Very Illogical

LOGICMETER™

Why? ______________________________

____

C. Class locator cards at NPS have the following format:

Locator Card					
	M	T	W	Th	F
09-10					
10-11					
11-12					
12-13					
13-14					
14-15					

How logical does this seem to you? (use the following LogicMeter)

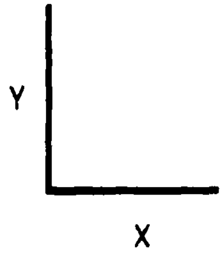
Very Logical Very Illogical

LOGICMETER$_{TM}$

Why? ______________________________

____

D. On the following graph, which axis would you label "TIME"?



Why? ______________________________

____

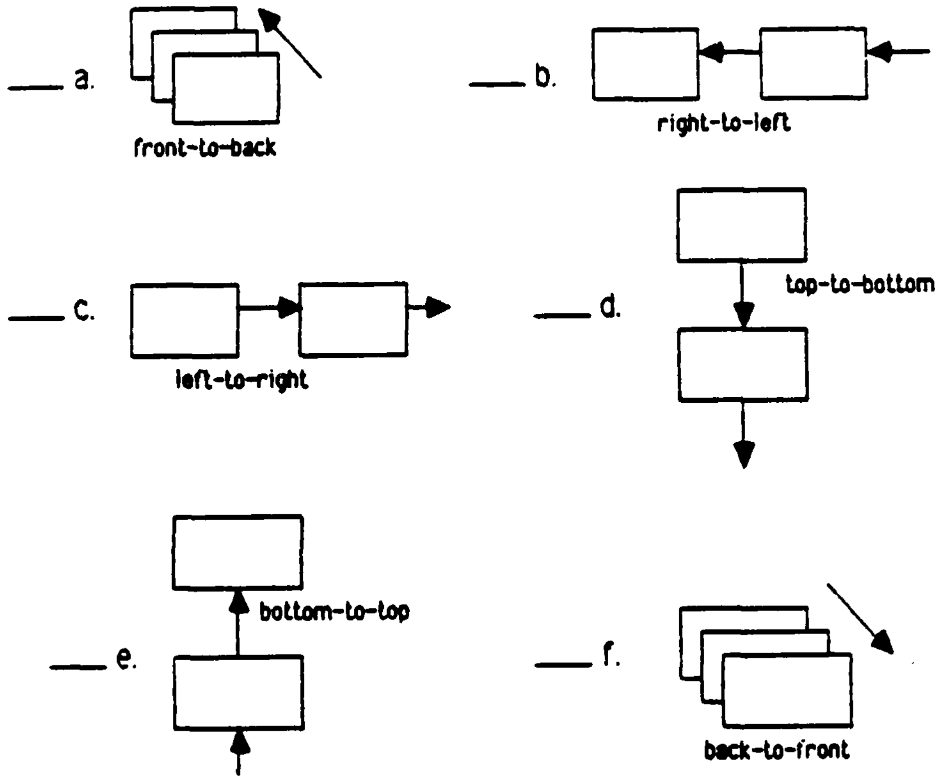
E. Telecommunications Scenario:

A message processing system is able to tell you the precedence of a message waiting in a queue. These four precedences are ROUTINE, PRIORITY, IMMEDIATE, and FLASH, with ROUTINE being the lowest precedence and FLASH the highest. These precedence categories provide rules for queue discipline. The following chart shows the speed with which these categories should be handled:

Servicing Rules	Speed of Service
FLASH	<10 min
IMMEDIATE	30 min
PRIORITY	3 hrs
ROUTINE	6 hrs

As you can see, knowing how long a message has been in the queue is important for speed of delivery. This message processing system will display the messages in precedence order with time-in-the-queue indicated. Which of the follow-

ing information storage schema would you use to best illustrate the precedence of incoming traffic?



Rank these 1 - 6, with 1 being the most desirable.

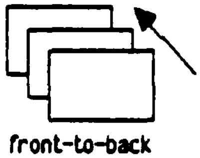
F. Air Scenario:

This scenario applies to a hypothetical 1990-configured F/A-18 aircraft using HARM and Harpoon weapons. This is a portion of a mission timeline. You are approaching an Orange Force Surface Action Group (SAG) in your aircraft.

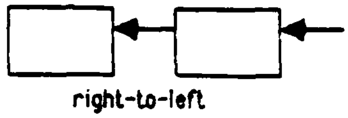
Time	Event No.	Event
1:11	14.1	Enter predicted SAG SA-N-3 missile range
	14.2	Turn 70° left toward target (SAG)
1:12	14.3	Second assigned target ship (from SAG) at HARPOON launch range
	14.4	Launch HARPOON
	14.5	Accelerate for HARM launch
	14.6	Enter predicted SAG SA-N-4 missile range
	14.7	Enter predicted SAG SA-N-6 missile range
1:12.5	14.8	Launch HARM, pre-briefed mode

These events appear on a cockpit display and require action be taken at the time indicated. Which of the following information storage schema would you use to best illustrate the chronological order of mission events?

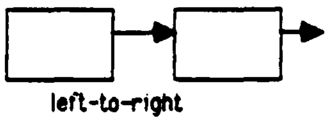
___ a.



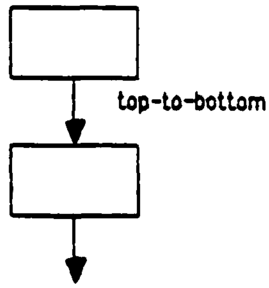
___ b.



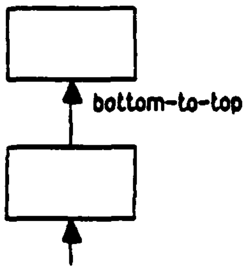
___ c.



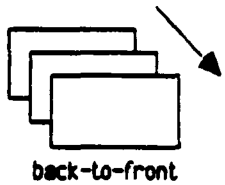
___ d.



___ e.



___ f.



Rank these 1 - 6, with 1 being the most desirable.

13. Comments: ____

____

____

____

____

LIST OF REFERENCES

1. Lind, J.H., *Cockpit Displays for a Knowledge-based System: The Intelligent Air Attack System,* paper presented at the IEEE National Aerospace and Electronics Conference (NAECON), Dayton, Ohio, 23-27 May 1988.

2. Gentner, D., and Stevens, A.L., *Mental Models,* Lawrence Erlbaum Associates, 1983.

3. *Air Force Systems Command Design Handbook 1-3,* "Human Factors Engineering", 3rd ed., Chapter 2, January 1977.

4. Huchingson, R.D., *New Horizons for Human Factors in Design,* McGraw-Hill Book Company, 1981.

5. Barnes, R.M., *Motion and Time Study,* John Wiley, 1968.

6. Fitts, P.M., *Handbook of Expermental Psychology,* John Wiley, 1959.

7. Sanders, M.S., and McCormick, E.J., *Human Factors in Engineering and Design,* McGraw-Hill Book Company, 1987.

8. Hall, A.D., and Fagan, R.E., *General Systems Theory and Design,* Rappaport Press, 1966.

9. Lind, J.H., *AI for the F/A-18 Mission: The Intelligent Air Attack System,* paper presented at the Fourth International Symposium on Aviation Psychology, Columbus, Ohio, 29 April 1987.

10. Naval Weapons Center Technical Memorandum 6161 (draft), *Intelligent Air Attack System (IAAS): Project and Product Definition,* by J.H. Lind, December 1987.

11. Naval Telecommunications Command, *Fleet Operational Telecommunications Program (FOTP) Manual*, 1 October 1985.

12. Naval Telecommunications Automation Support Center, *Naval Communications Processing and Routing System (NAVCOMPARS): System/Subsystem Specification*, NAVTASC Document Number 15X7001, SS-01E Volume 1, 1986.

13. Naval Telecommunications Automation Support Center, *NAVCOMPARS Traffic Management*, NAVTASC Document Number 15X7001 TR-01D, November 1986.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, VA 22304-6145	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, CA 93943-5002	2
3.	Prof. Judith H. Lind Naval Postgraduate School Code 55Li Monterey, CA 93943-5000	2
4.	Human Factors Branch Code 3152 Naval Weapons Center China Lake, CA 93555	2
5.	Prof. Kenneth Funk Department of Industrial and Manufacturing Engineering Oregon State University Corvallis, OR 97331	1
6.	LT Joyce Fleischman NAVCOMSTA Puget Sound Naval Submarine Base, Bangor Bremerton, WA 98315-5600	5
7.	Mr. and Mrs. G. Daugherty 1242 Colvin Blvd. Kenmore, NY 14223	1
8.	Ms. Helen Shron 85 Clark Rd. Kenmore, NY 14223	1
9.	Prof. Dan C. Boger Naval Postgraduate School Code 54Bo Monterey, CA 93943-5000	1
10.	Prof. Benjamin J. Roberts Naval Postgraduate School Code 54Ro Monterey, CA 93943-5000	1